# The role and value of flexible CCS: UK perspective

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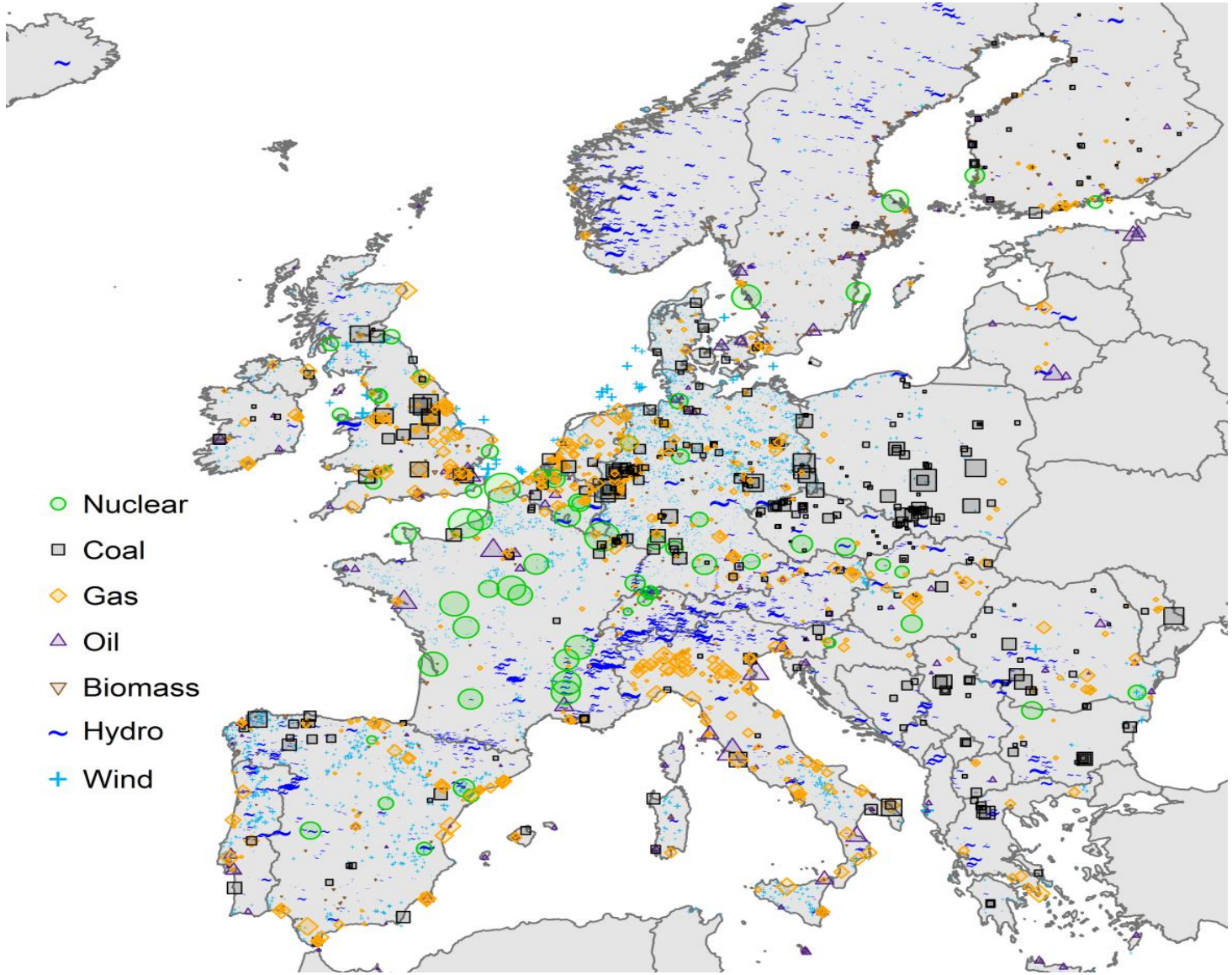
# Context for this work: zero emissions UK in 2050

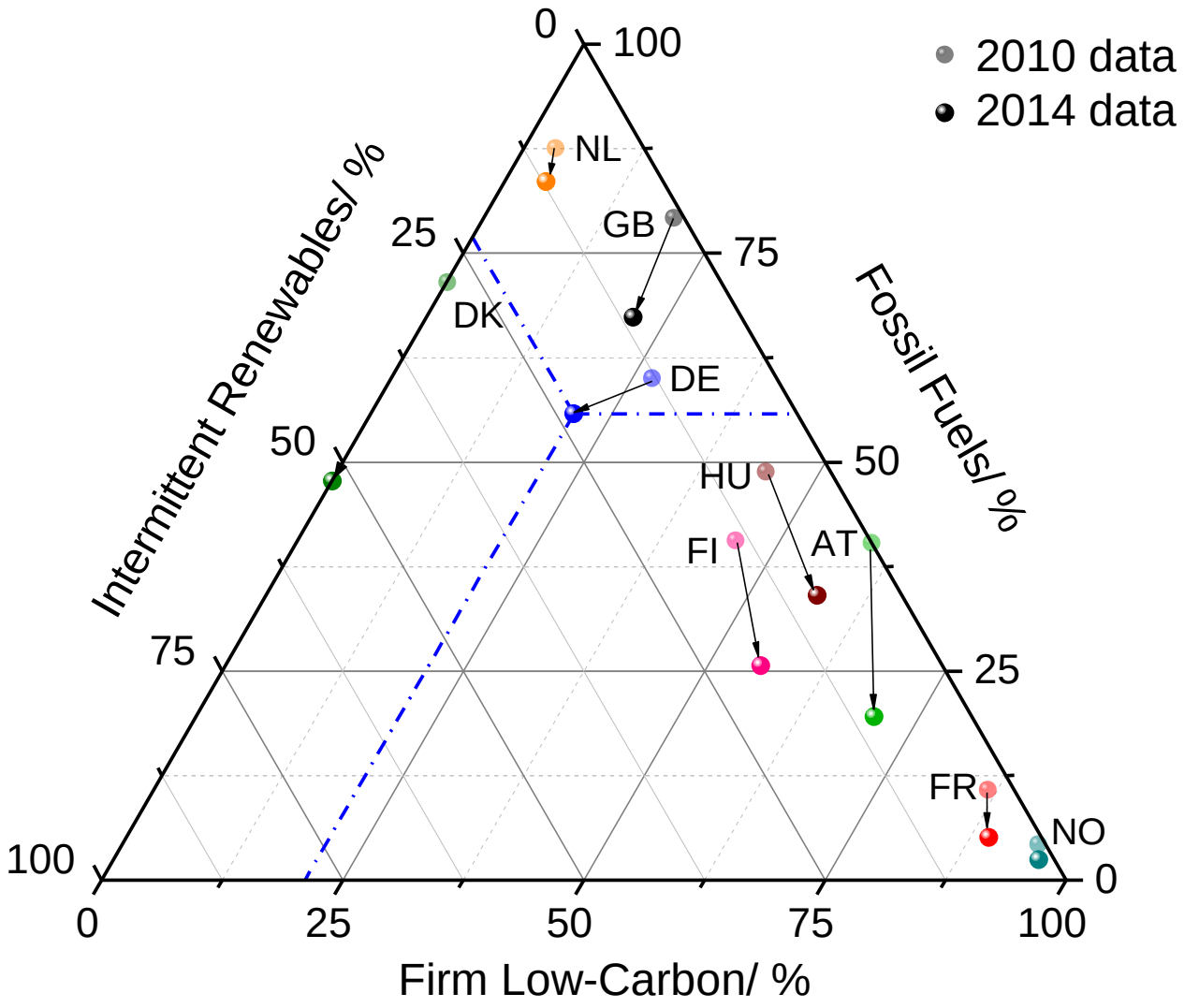

https://www.gov.uk/government/news/uk-becomes-first-major-economy-to-pass-net-zero-emissions-law

# The European electricity system is diverse




Bassi et al., “Bridging the gap: improving the economic and policy framework for carbon capture and storage in the European Union”, 2015

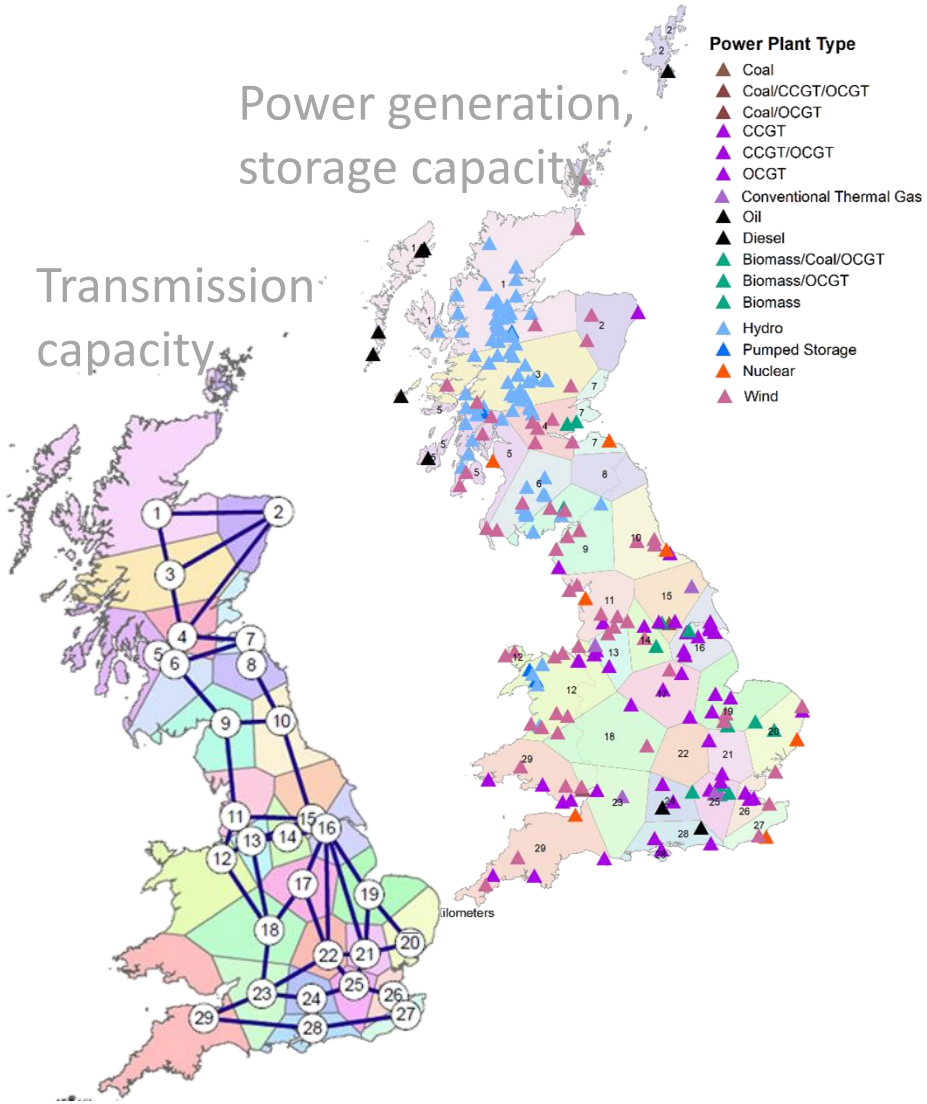
# Europe aiming* for climate-neutrality by 2050




*maybe: some central European countries are being unhelpful here…

Heuberger et al., Energy Environ. Sci., 2016

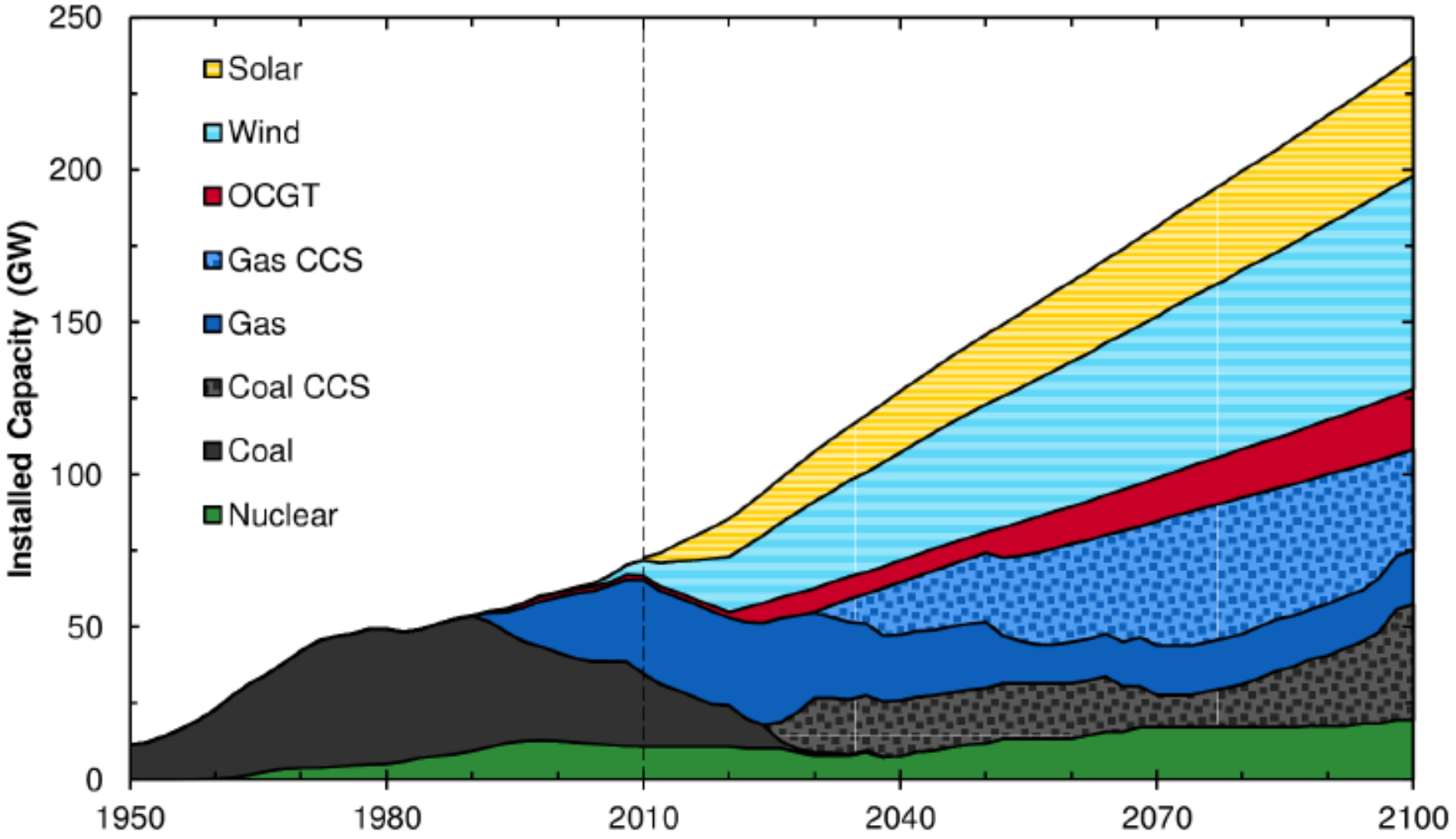
# Electricity Systems Optimisation




| | | |
|---|---|---|
| $\forall i \in I$<br>$\forall a \in A$ | **Capacity expansion** | • Initial supply and transmission capacity<br>• Build rate constraints (supply, store, transmission)<br>• Life time constraints<br>• Maximum resource constraints |
| $\forall c \in C$ | **System-wide constraints** | • Electricity demand<br>• Reserve requirements<br>• Inertia requirements<br>• Emission target |
| $\forall z \in Z$ | **Transmission** | • Transmission between zones |
| $\forall t \in T$ | **Tech.-wise constraints** | • Power, Reserve, inertia provision<br>• Flexibility of generation/storage units<br>• Carbon emissions by technology<br>• Uptime and downtime |
| | **Integer scheduling** | |
| $sum$ | **Objective** | min { CAPEX + mode-specific OPEX } |

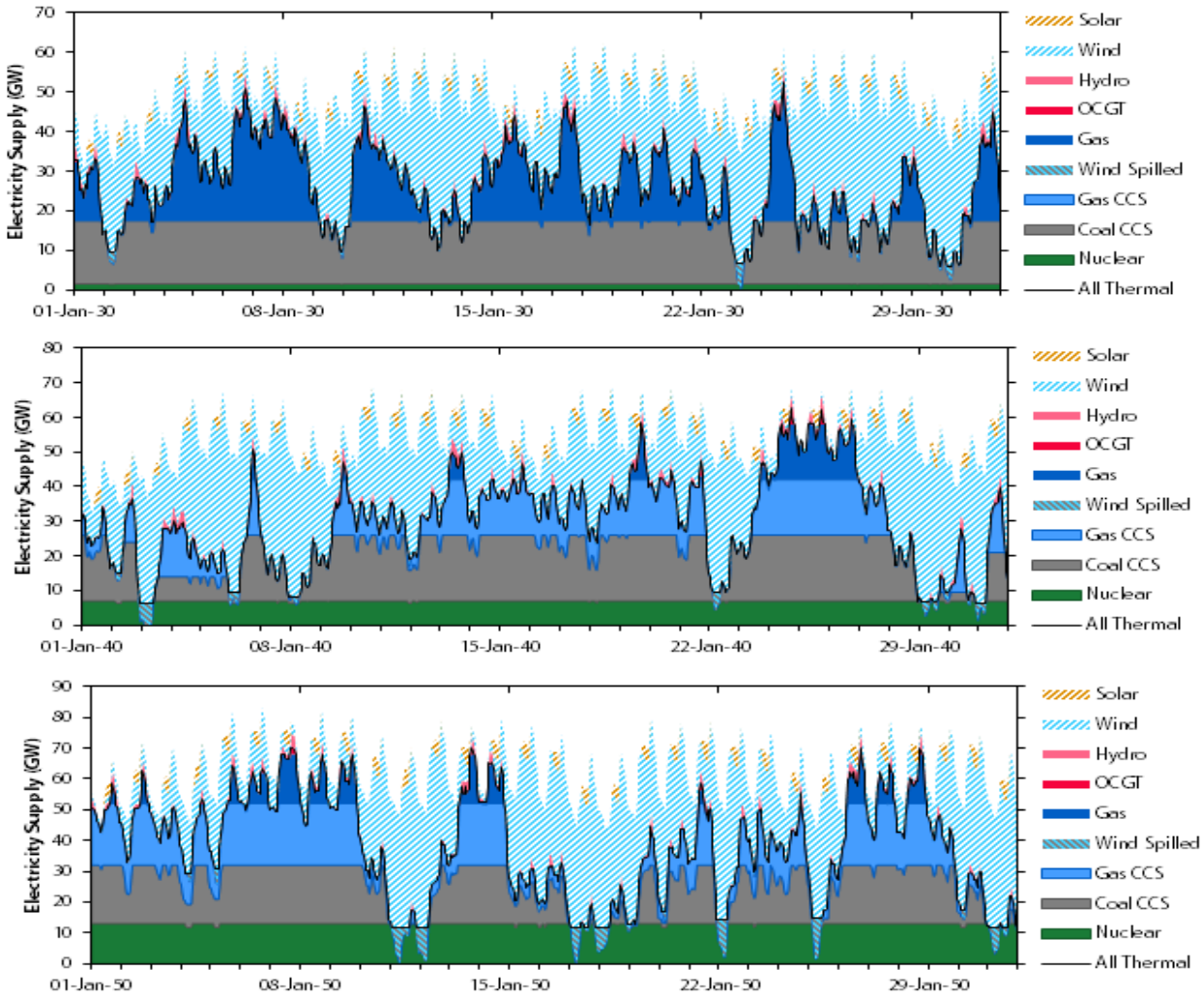
Building on: CF Heuberger, E Rubin, I Staffell, N Shah, N Mac Dowell, *Applied Energy*, 2017, 204: 831–845

# How might the UK system evolve?



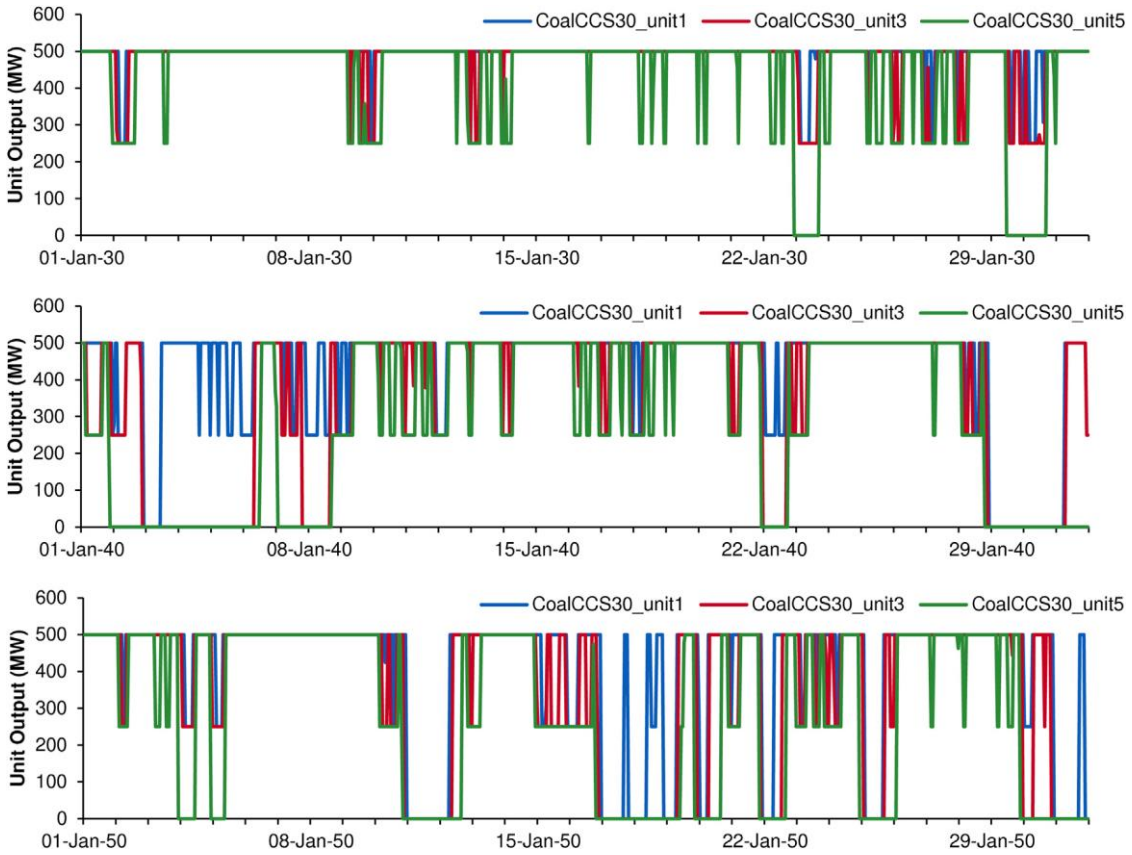

Mac Dowell and Staffell, Int. J. GHG Con., 2016

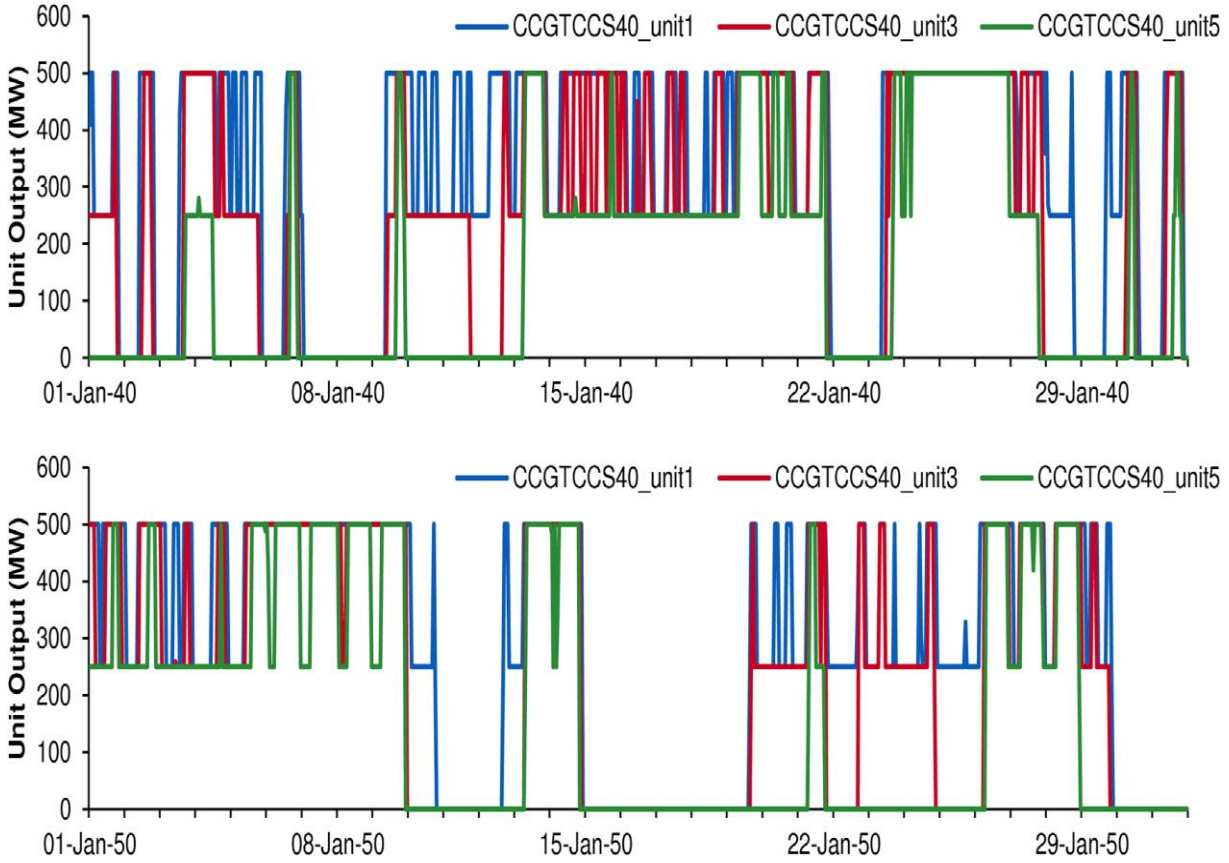
# Dispatch patterns evolve with time




Mac Dowell and Staffell, Int. J. GHG Con., 2016

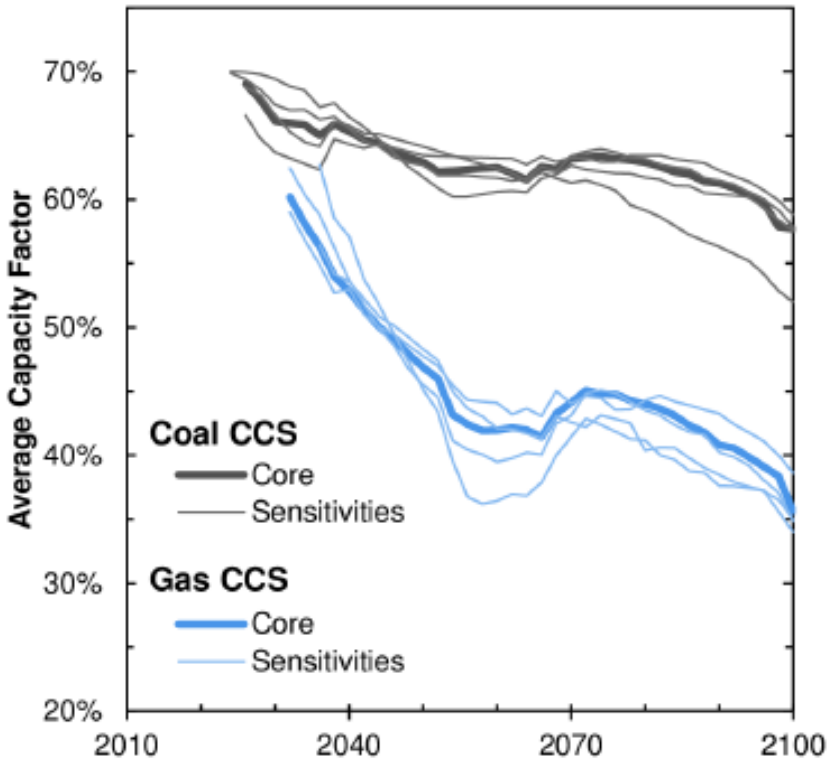
# Unit dispatch of CCS

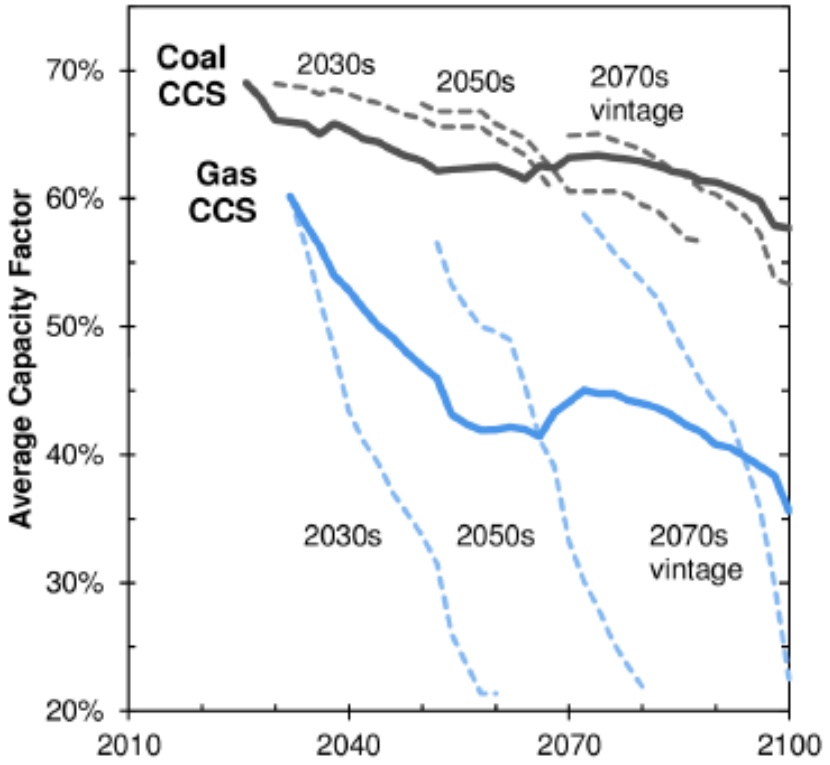



Mac Dowell and Staffell, Int. J. GHG Con., 2016

# How might CCS plant behaviour change?



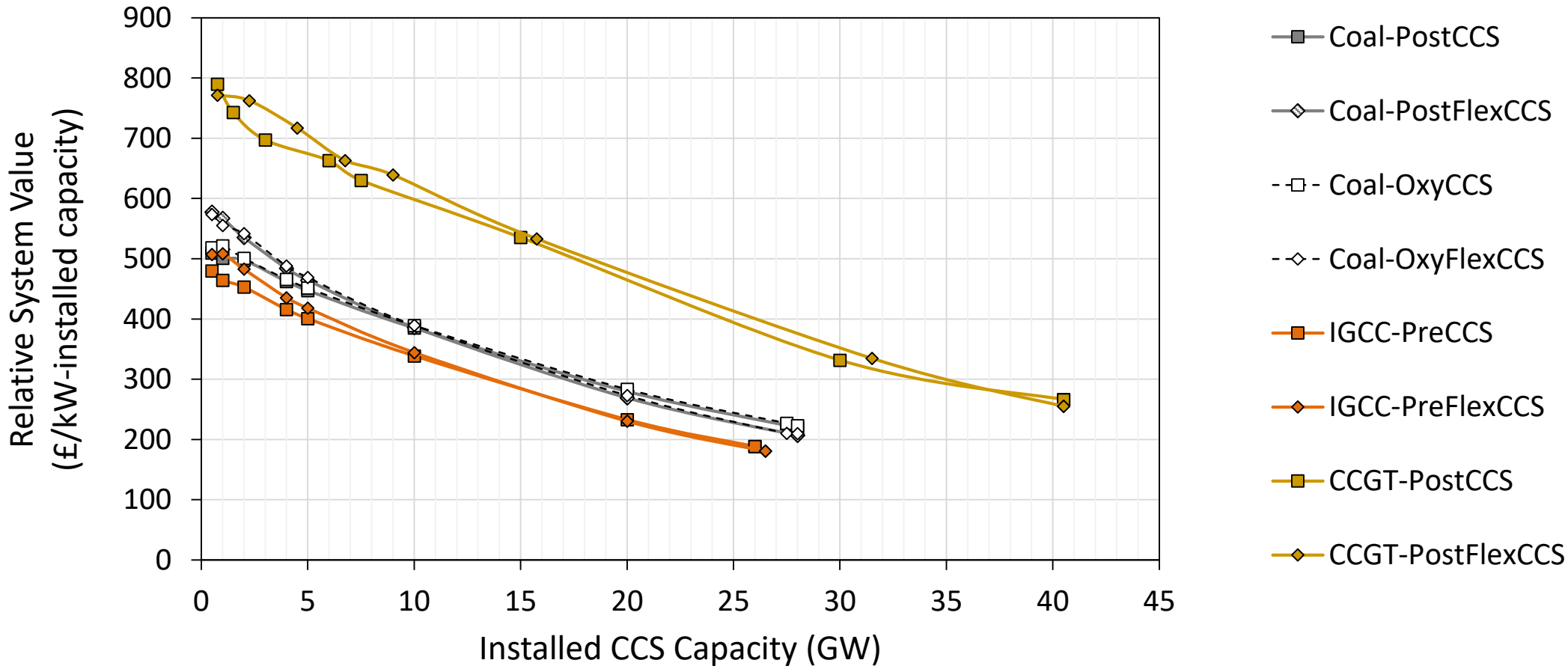




Mac Dowell and Staffell, Int. J. GHG Con., 2016

# Some thoughts in response to Scott's webinar

- Can we quantify the value of "flexible" CCS?
- How much CCS are we likely to deploy, and how will it be used?
- Should there be a market premium for flexibility?
- Should we think about > 90% capture?
- What can solvent technology contribute?
- How do CCS plants interact with $CO_2$ transport infrastructure?
- Might the $CO_2$ storage "tail" wag the dog?

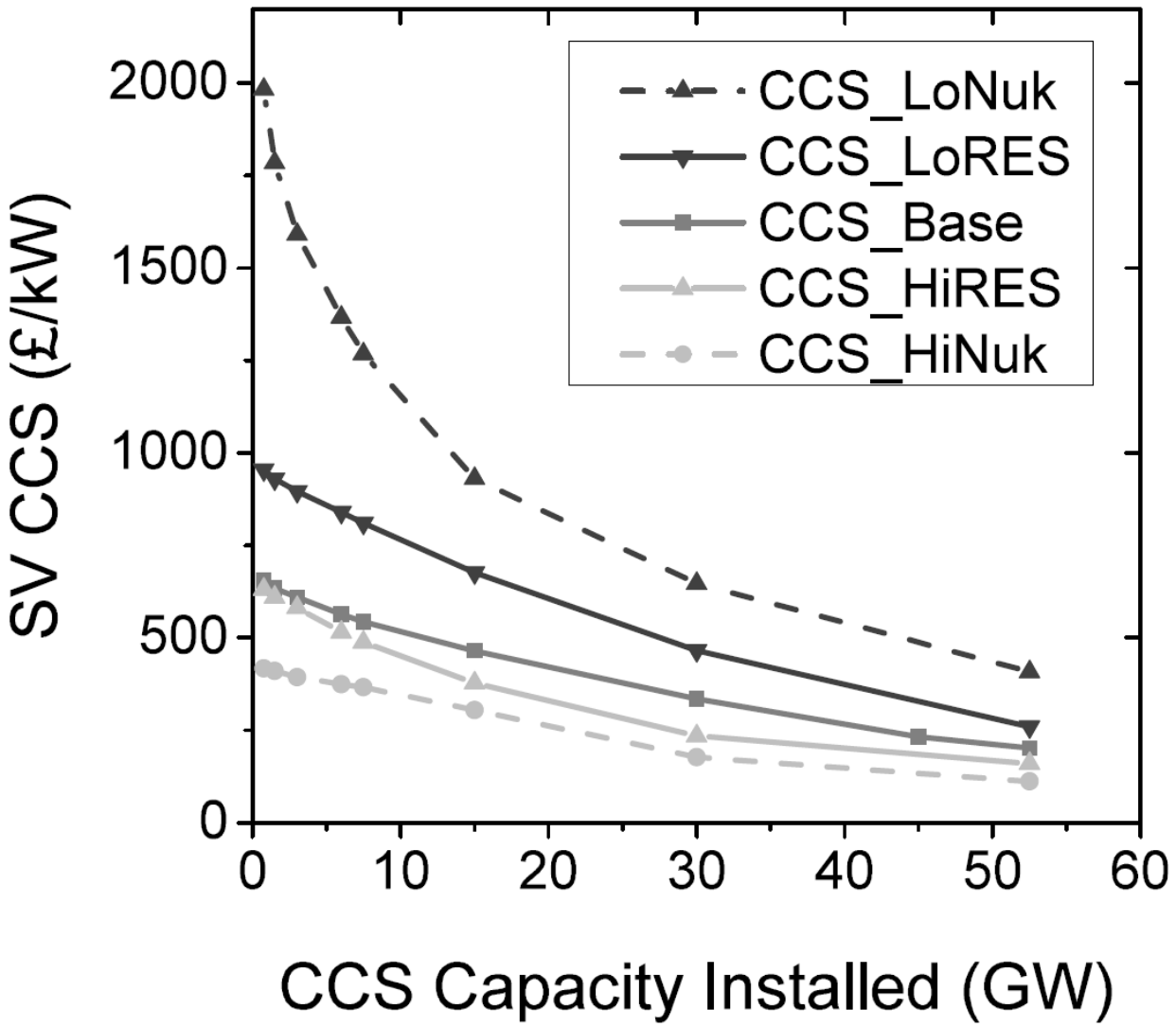
# Low CAPEX CCS provides the greatest value




Heuberger, *et al*, Computers and Chemical Engineering, 2017

Heuberger, *et al*. Valuing Flexibility in CCS Power Plants – FlexEVAL project for the IEAGHG, 2016

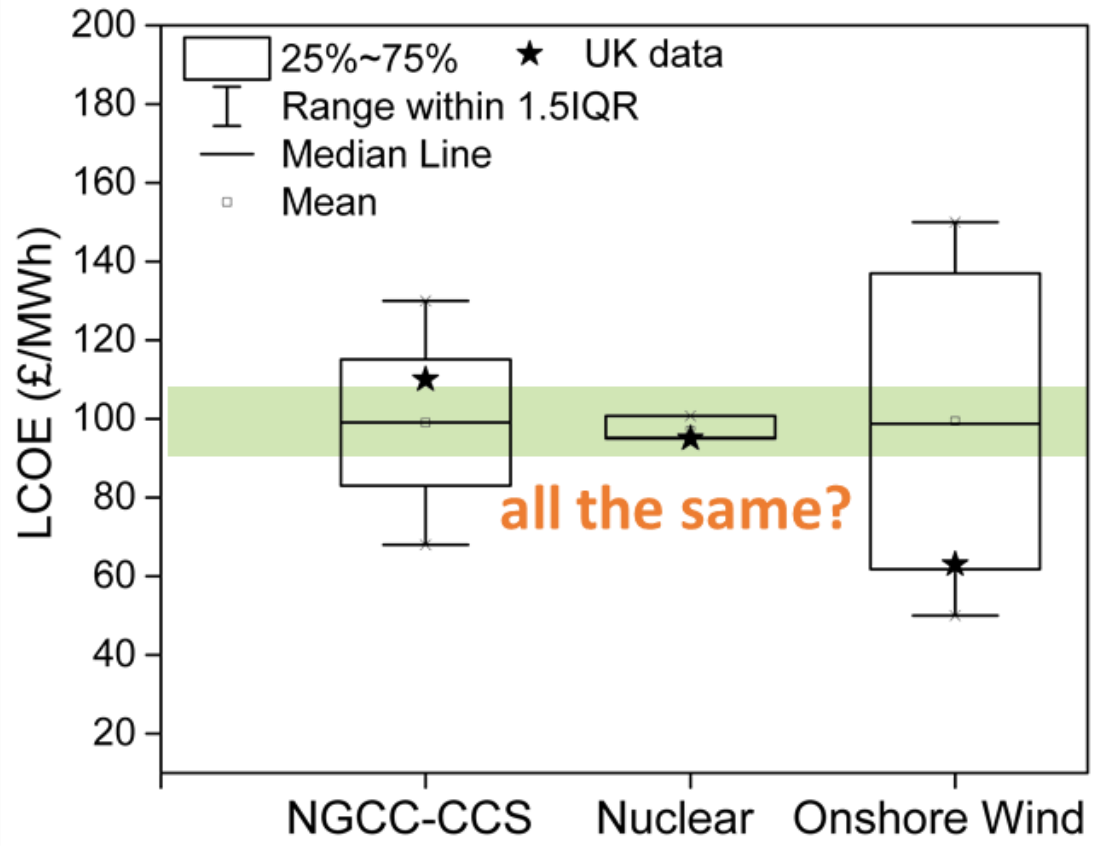
# Value of CCS is context specific



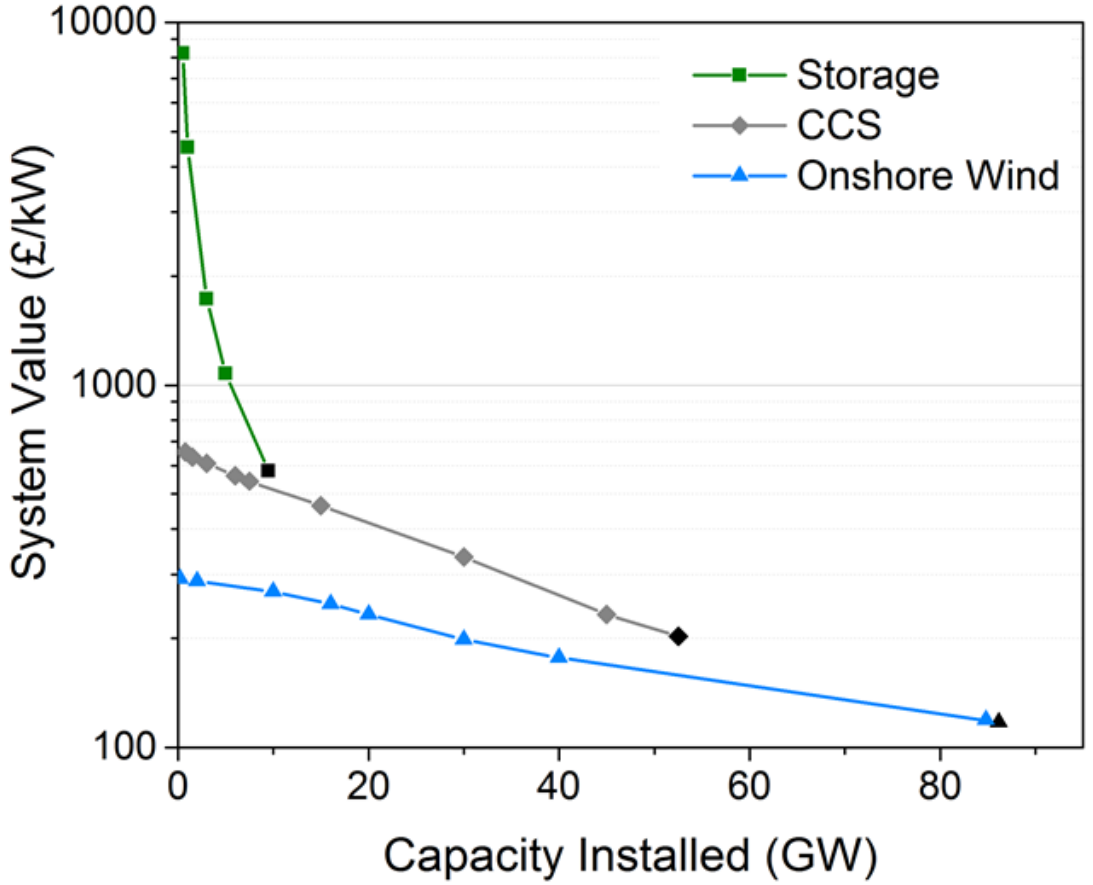

Heuberger, *et al*, Computers and Chemical Engineering, 2017

# Value ≠ cost

## LCOE

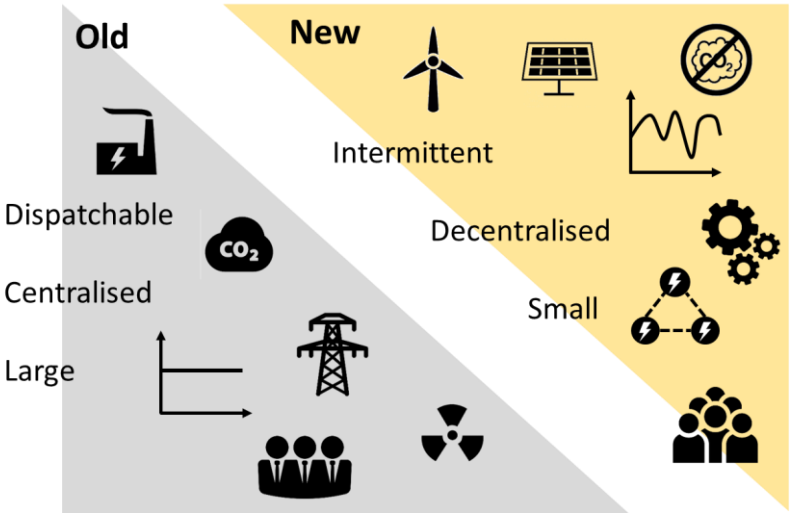



## System Value




Heuberger, *et al*, Computers and Chemical Engineering, 2017

# Which technology parameters matter?




The power system is changing…

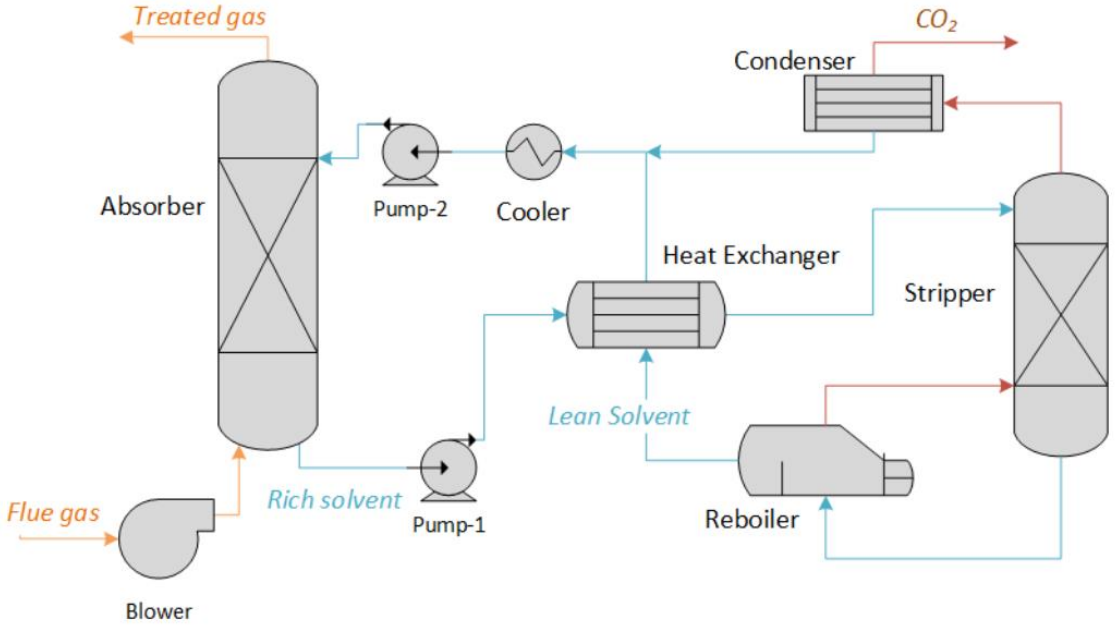
"+" → "+++" = low → high value

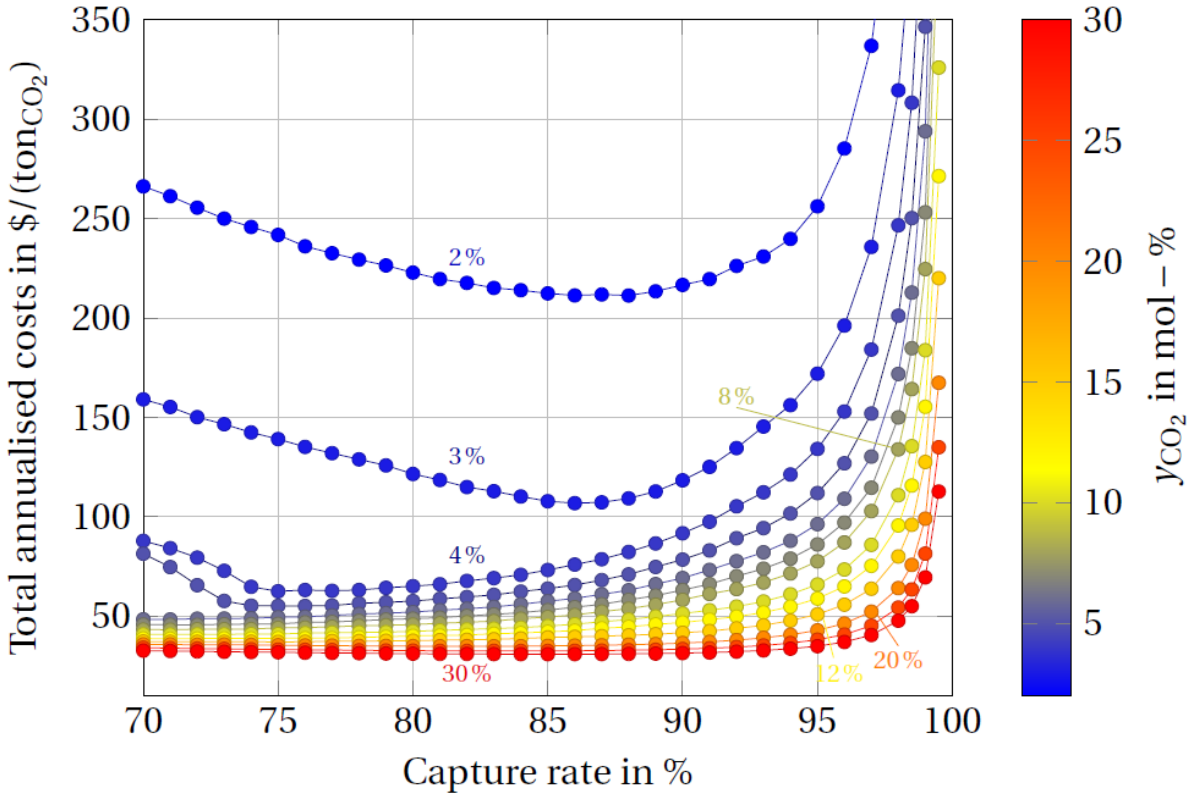
*modelled as minimum stable generation point, up-/down time

| Technology Feature | Value in future power systems |
|---|---|
| High Efficiency | + |
| High Flexibility* | ++ |
| Low CAPEX | +++ |
| Dispatchability | +++ |
| Firm capacity/ancillary service provision | +++ |
| Low OPEX | + |
| High Rate of Deployment | ++ |

Schnellmann, et al, Int J GHG Con, 2018

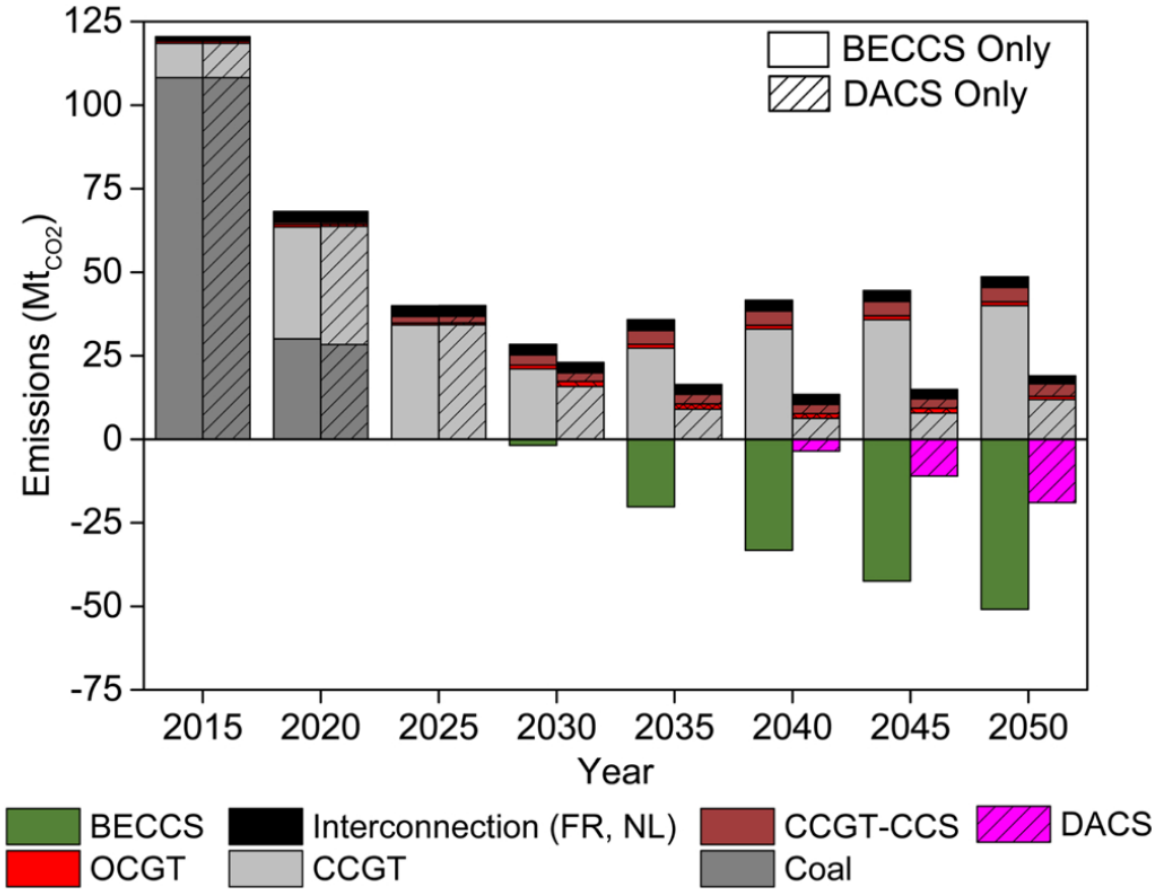
# Should we think about > 90% capture?

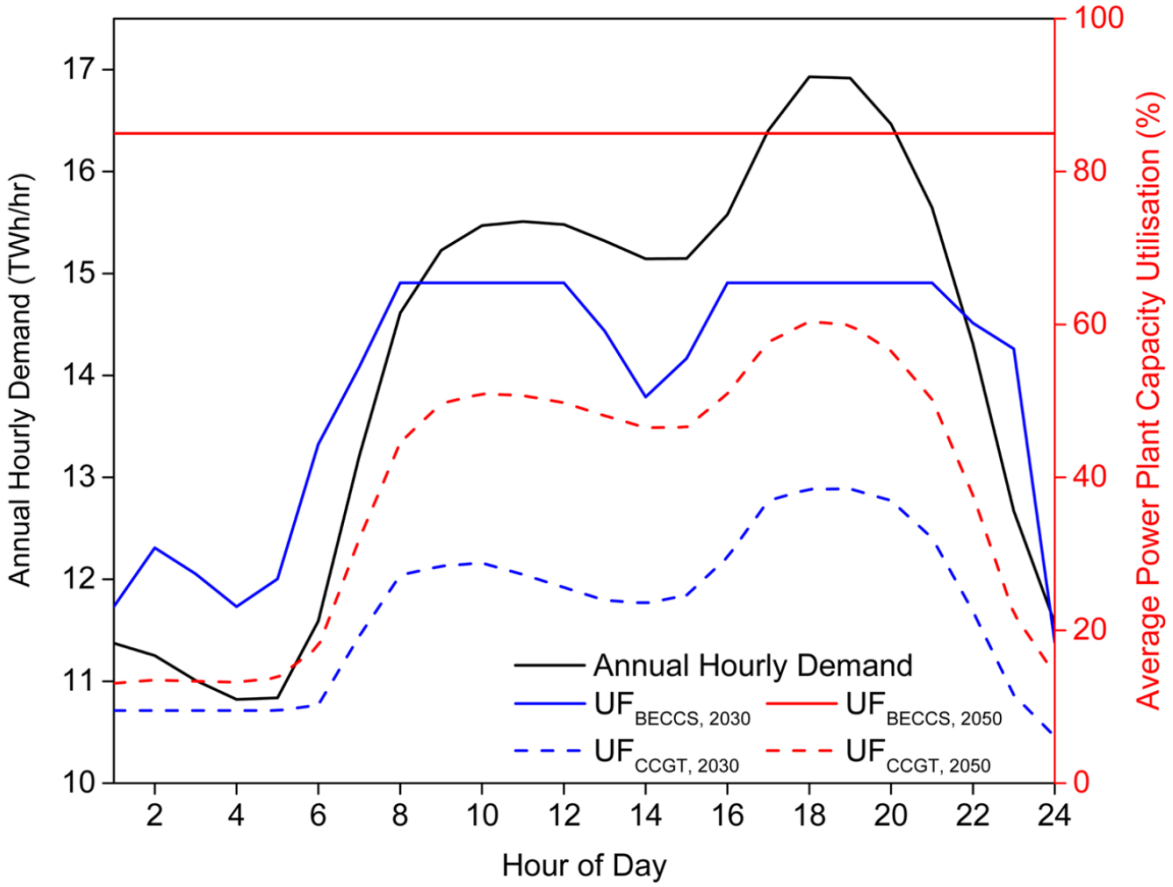



Brandl, *et al*, Int J GHG Con, 2019

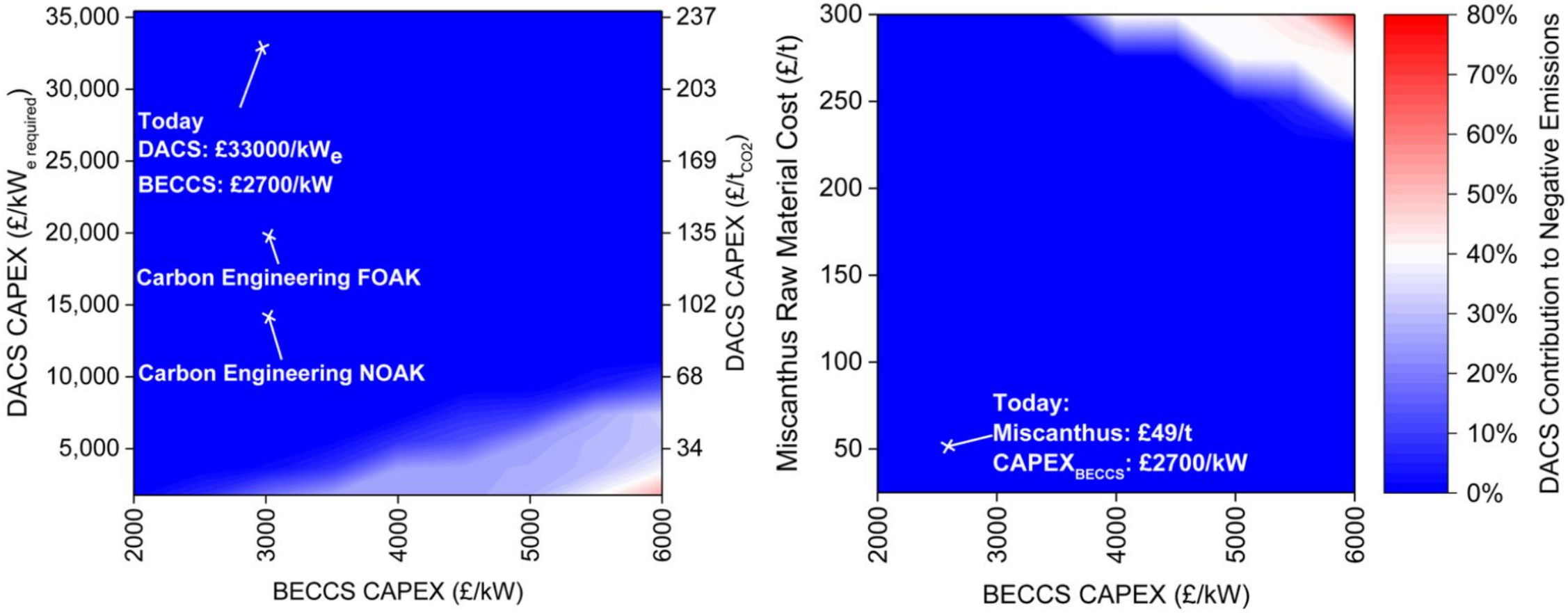
# Interactions between CCGT and NETs



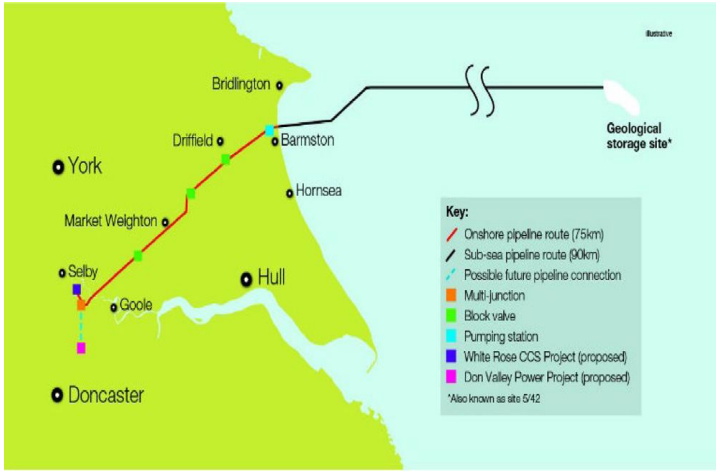

Daggash, *et al*, Int J GHG Con, 2019

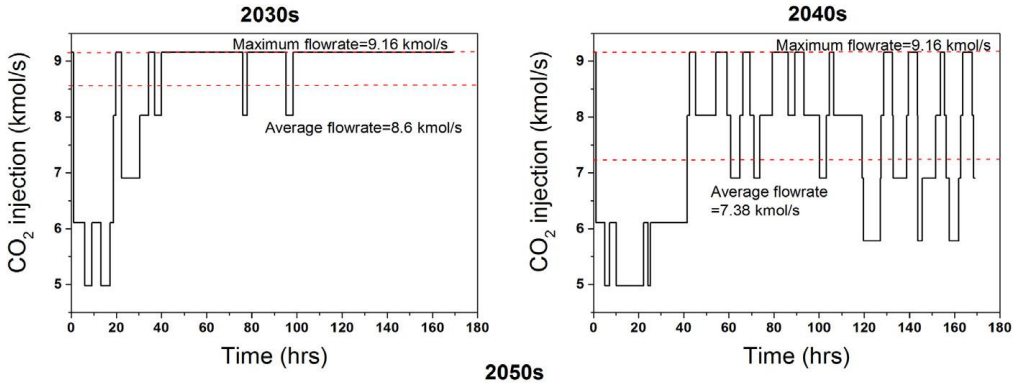
# Interactions between BECCS and DACS




Daggash, *et al*, Int J GHG Con, 2019

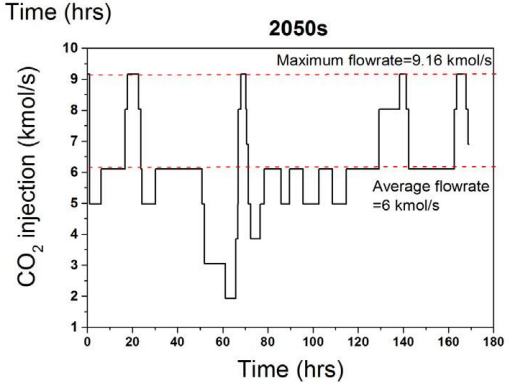
# How does CCS plant interact with transport?

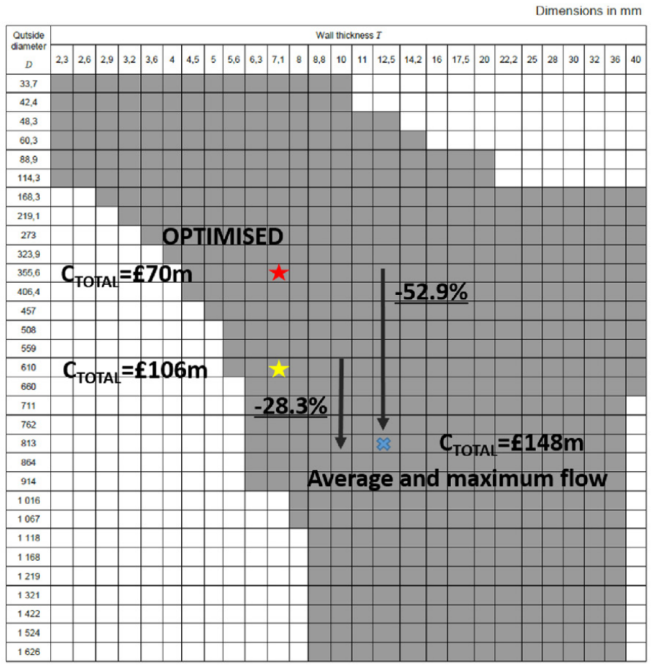


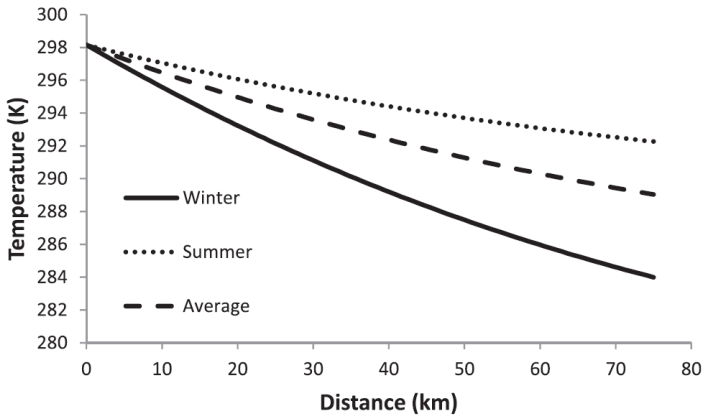



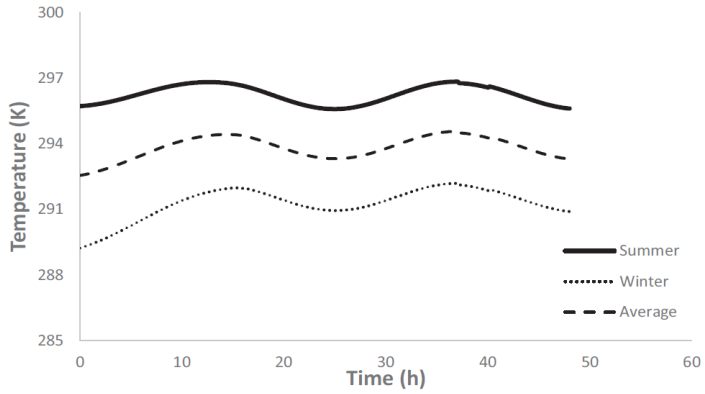






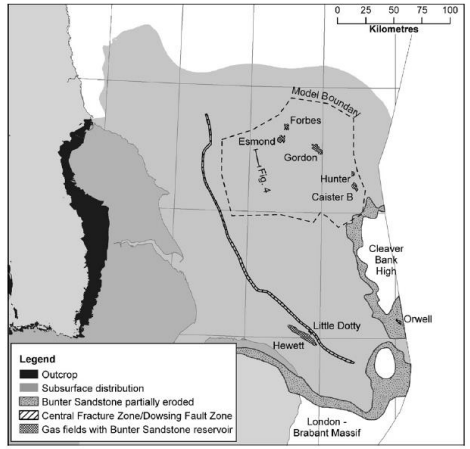



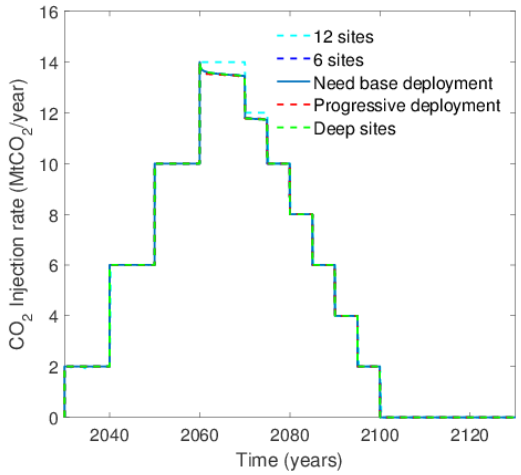

Mechleri et al, ChERD, 2017

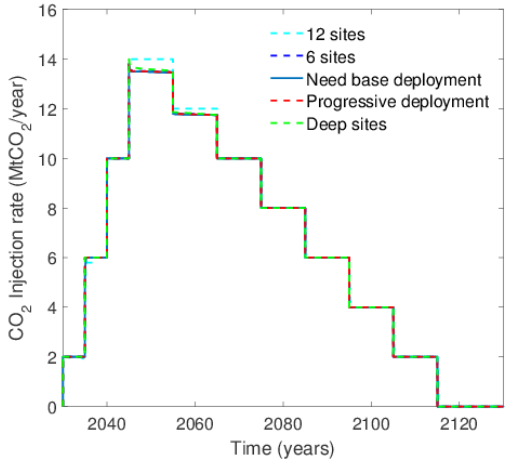
# How does $CO_2$ storage respond to varying $CO_2$ injection?

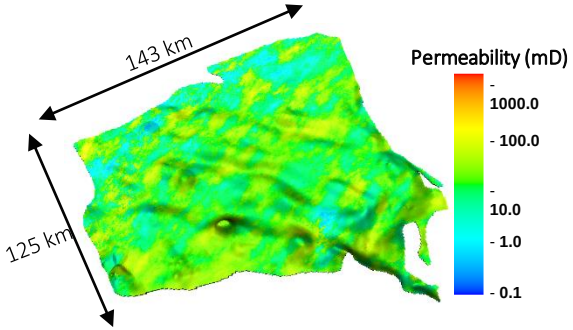
Reservoir model of the UK Bunter Sandstone Saline Aquifer (Noy et al. 2010)




Injection rates characteristic of UK CCS deployment




- Detailed reservoir simulation implies that UK-type storage infrastructure can accept time varying injection rates without problems

Kolster et al, Int J GHG Con, 2018

# Some conclusions…

- From a systems perspective, “flexible” CCS seems to add value
  - Increased CCS flexibility = reduced curtailment of renewable energy
- Regardless of iRES deployment, CCS capacity deployed remains constant
  - The services provided by CCS will likely change
- Higher rates of capture should be pursued
  - Low marginal cost, appreciable system value
- Efficiency is not as important as it used to be
  - Reducing CAPEX is of paramount importance
- In this context, solvent development can help
  - Shift the cost structure from CAPEX dominance – but don’t forget the gas phase
- The T&S “tail” will not wag the “CCS dog” – probably…